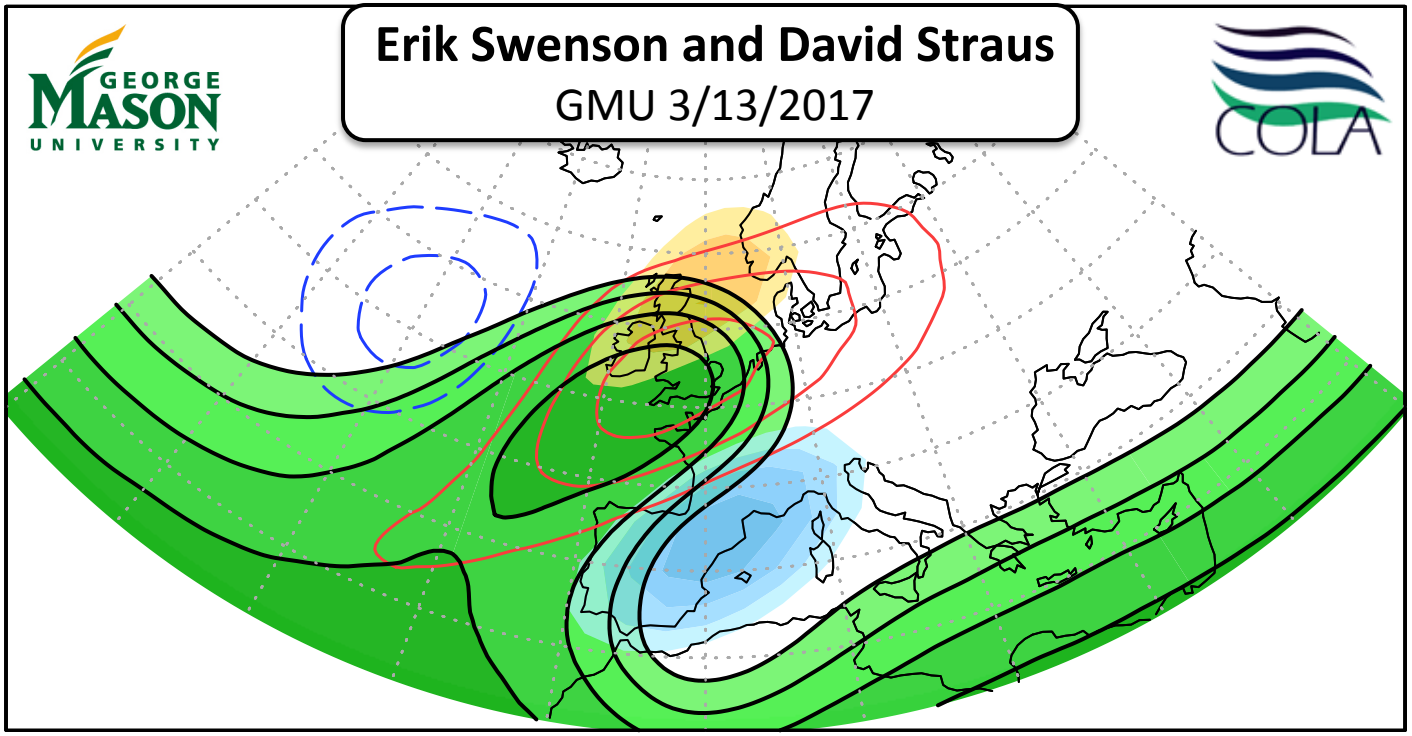
Rossby wave breaking and transient eddy forcing during Euro-Atlantic circulation regimes



Part of broader collaborative work with
Gang Chen (UCLA), Jian Lu (PNNL) and L. R. Leung (PNNL)

Motivation

- Rossby wave breaking (RWB) evident in overturning of potential vorticity (PV) near the tropopause

- RWB plays a crucial role in reorganizing transient eddies whose fluxes trigger/ reinforce persistent changes in large-scale circulation

- The relative roles of cyclonic (CWB) and anticyclonic wave breaking (AWB) have yet to be quantified in terms of the full 3-D baroclinic transient eddy forcing (momentum and heat fluxes)

- We estimate the roles of CWB and AWB for the development of different Euro-Atlantic circulation regimes, as well as examine how well this is simulated in seasonal re-forecasts (and whether or not horizontal resolution is important)

Unique Data Set of ECMWF Model Simulations and Reforecasts

Minerva Project

Atmospheric Model (IFS) coupled to NEMO Ocean Model (1.0 →0.33 deg, 24 L)

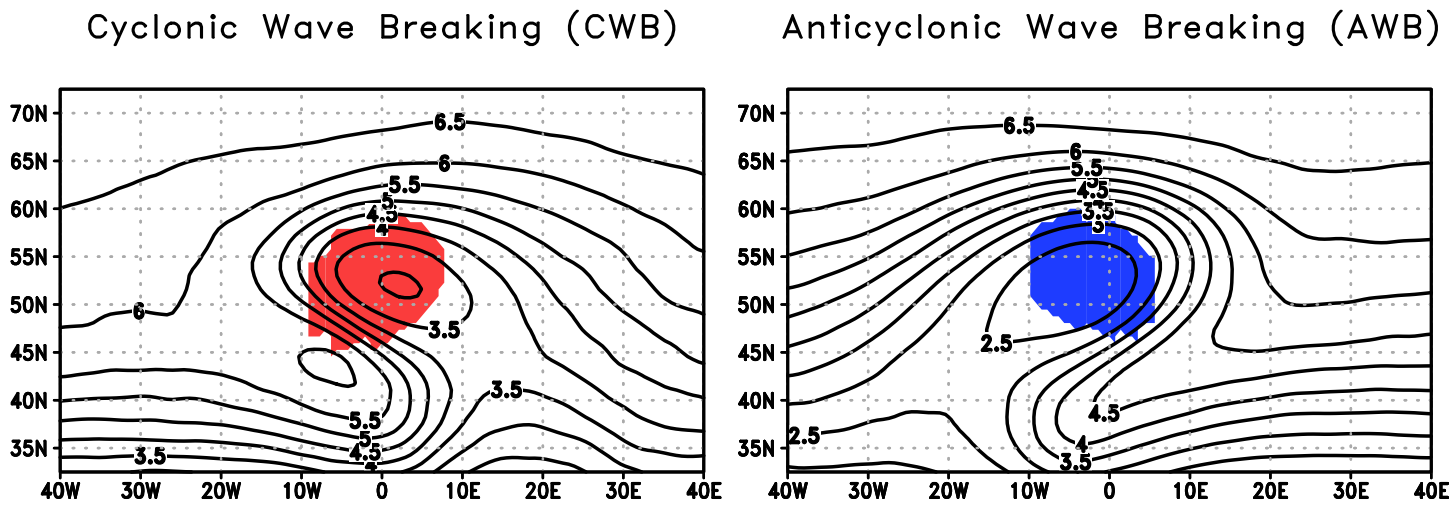
Ensemble Reforecasts with 01 Nov. Start Dates

16 Nov. – 31 March analyzed

Resolution	Delta λ, Δx	Years	Ens. Size
T319 L91	0.56°, 62 km	1980-2010	15
T639 L91	0.28°, 31 km	1980-2010	15
T1279 L91	0.14°, 16 km	1980-2010	15

Observational analysis: ERA Interim Reanalysis (ERAI)

RWB detection



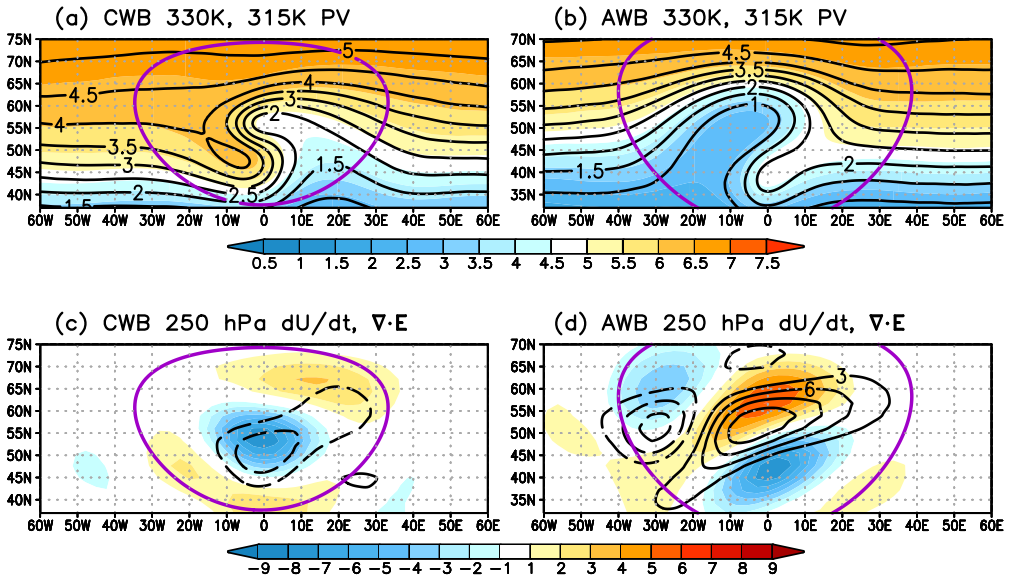
- Overturning of Ertel PV at 330 K or 315 K (Strong & Magnusdottir 2008)
- Gradient constraint
- Spatial scale constraint
- Partition according to direction of overturning (CWB or AWB)

RWB role estimation

- Given ***R***, radius of circle with same area as that of wave breaking event, fields within 4***R*** of event centroid are considered related

CWB: easterlies (jet weakening)
AWB: dipole (poleward shift)

- Impact of transient eddies
➔ local EP flux divergence ($\nabla \bullet E$)



Composite of all CWB and AWB events in ERAI

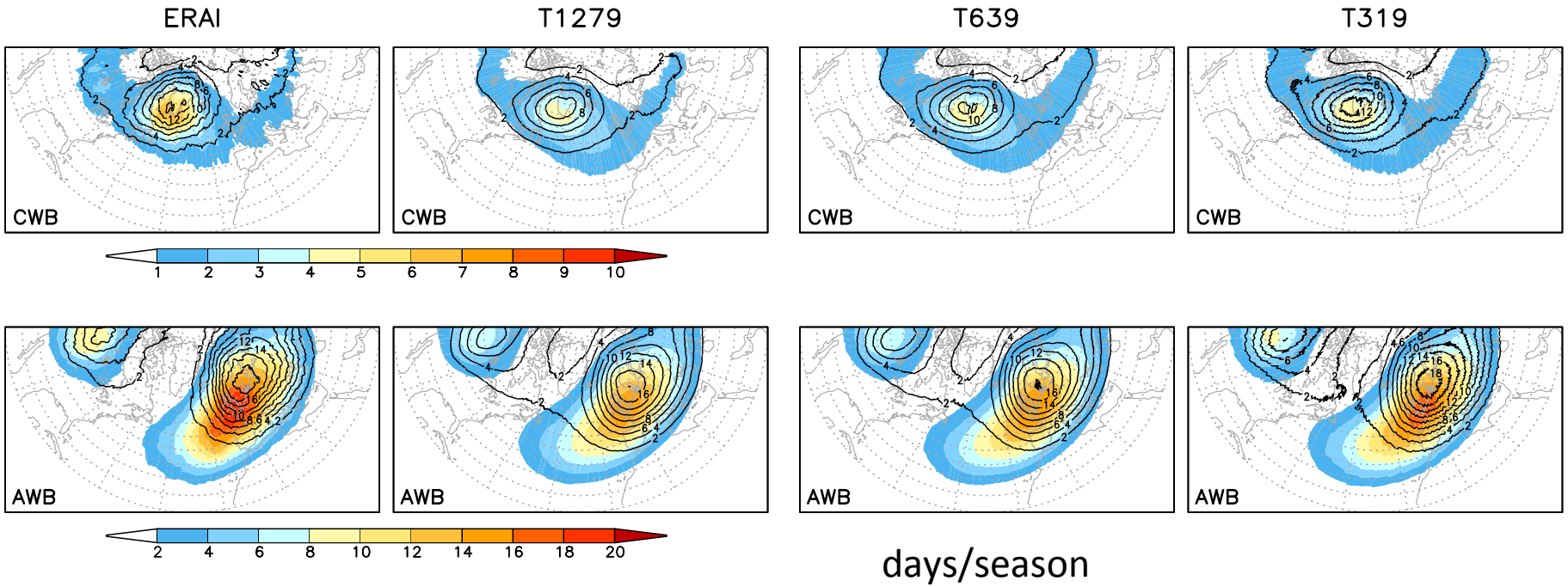
- Time mean zonal wind tendency

$$\nabla \cdot \boldsymbol{E} = \left[\frac{\cos\phi}{2}\frac{\partial}{\partial x}(\overline{v'^2} - \overline{u'^2}) - \frac{\partial}{\partial y}(\overline{u'v'}\cos\phi)\right] + \left[-\cos\phi\frac{\partial}{\partial p}(R_d f p\frac{\overline{v'T'}}{S} + \overline{u'\omega'})\right]$$

momentum flux heat flux

- Neglects low frequency terms, diabatic heating, friction

Climatological frequency of CWB and AWB



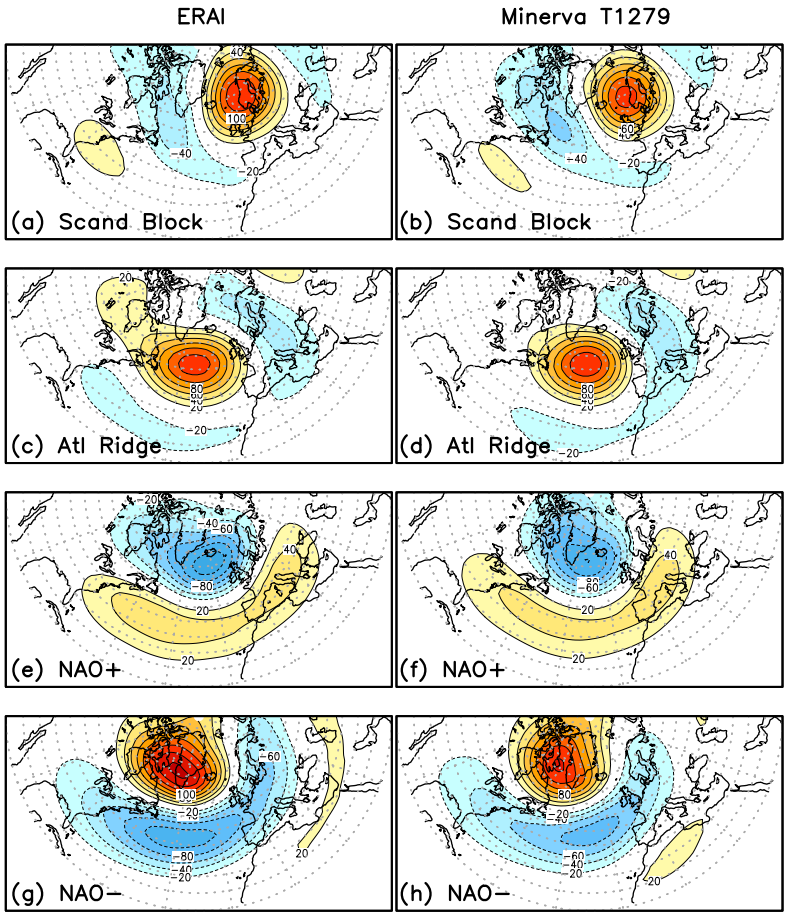
- Maxima simulated well; increasing resolution does not improve frequency of CWB and AWB; if anything, T319 (~62 km) is most realistic

Euro-Atlantic circulation regimes

- Identified through k-means cluster analysis of 500 hPa geopotential height (Z500)

- Scandinavian Blocking, Atlantic Ridge, NAO+, NAO-

- Highly reproducible in all Minerva re-forecasts

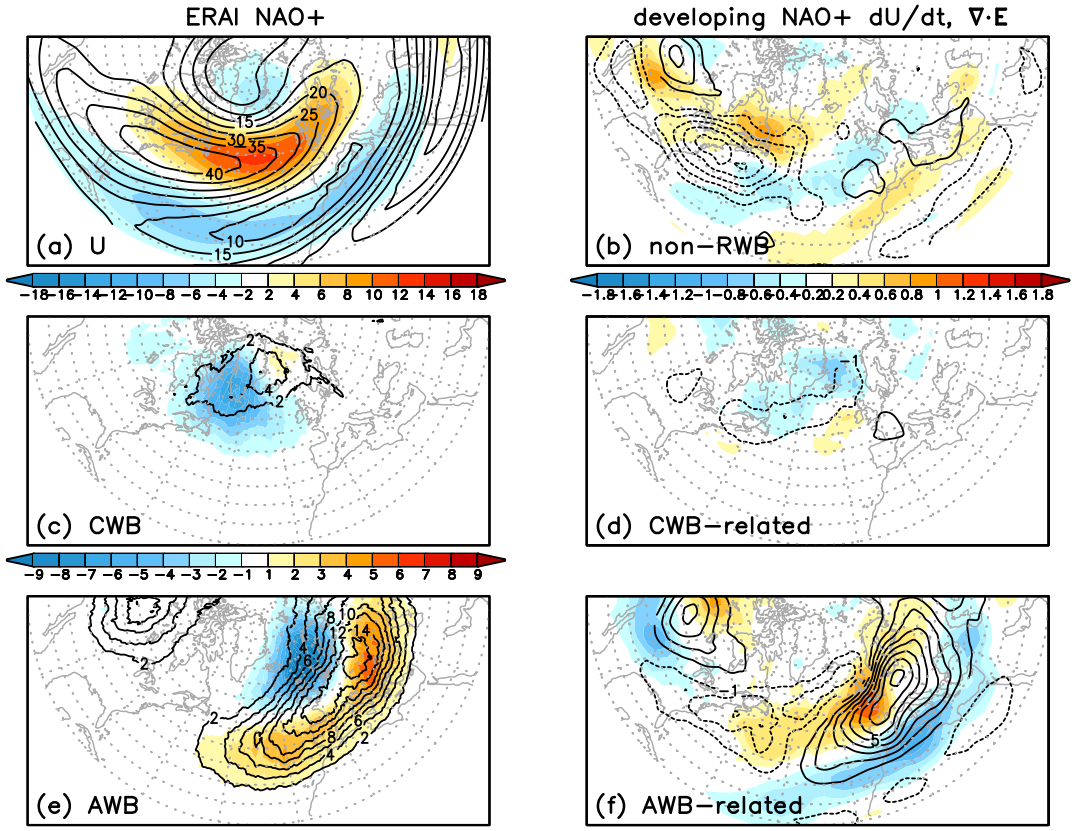


ERA Interim NAO+

- Jet extension

- Reduction in CWB, poleward shift in AWB

- During development, jet extension in E. Atl. occurs during AWB and is reinforced by transient eddies (positive $\nabla \cdot E$)



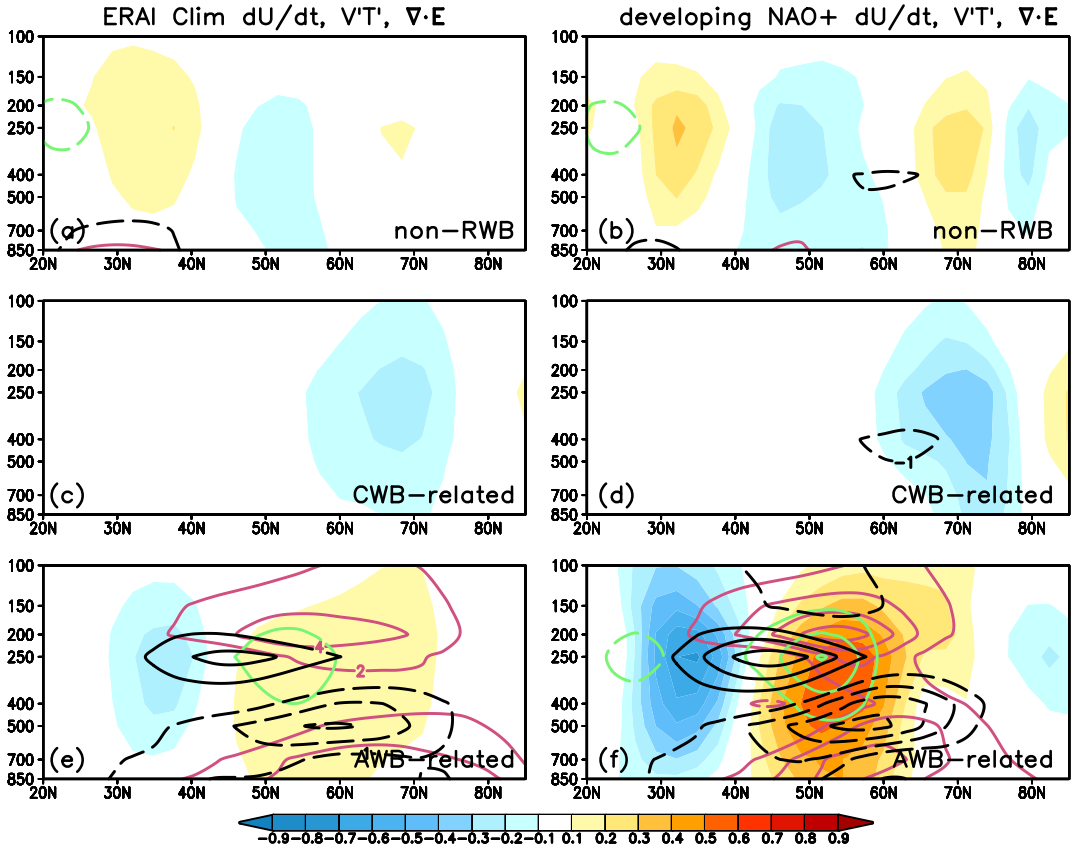
Developmental phase defined when anomalous Z500 has increasing pattern correlation with NAO+ cluster pattern

ERA Interim NAO+

Zonal average over
E. Atl./W. Europe
(20° W to 40° E)

- Jet extension/poleward shift (shading) normally linked to AWB
- During AWB, maxima in transient heat flux (***v'T'***) at 850 hPa and 200 hPa
- Reinforces westerlies via $\nabla \bullet \boldsymbol{E}_V$ as much as $\nabla \bullet \boldsymbol{E}_H$ (momentum fluxes)

- Enhanced substantially during NAO+ development



d***U***/d*t* (shading); contours: ***v'T'***, $\nabla \bullet \boldsymbol{E}_H$, $\nabla \bullet \boldsymbol{E}_V$

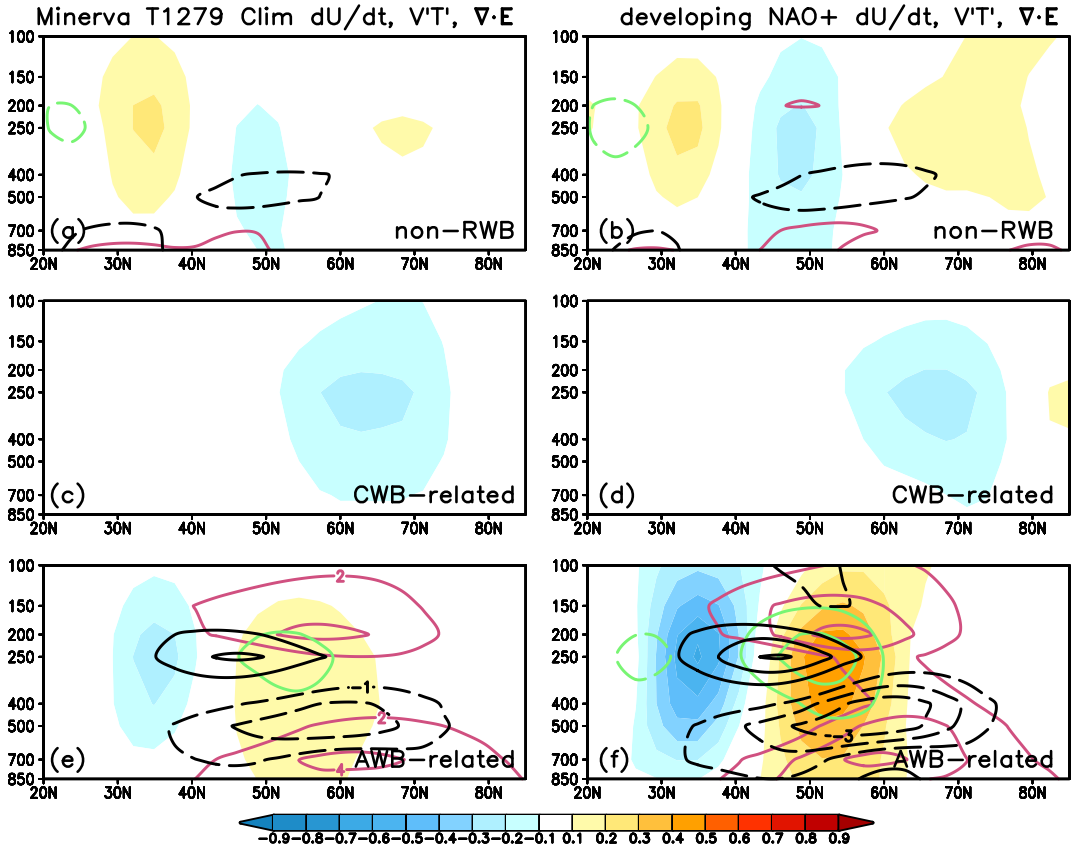
Minerva T1279 NAO+

Zonal average over
E. Atl./W. Europe
(20° W to 40° E)

- Simulated fairly well in Minerva T1279

- Frequency of CWB and AWB simulated quite well (not shown)

- Slightly weaker transient eddy activity ➔ weaker role of AWB during NAO+ development
- Consistent with weaker simulated NAO+ zonal wind anomalies



d***U***/d*t* (shading); contours: ***v'T'***, $\nabla \bullet E_H$, $\nabla \bullet E_V$

Further results

- Changes in CWB and AWB during various regimes consistent with Michel & Rivière
- Large increase in CWB during NAO- when CWB plays dominant role (low-level transient heat fluxes in the W. Atl. seem to be important)
- Ridge growth is coincident with AWB during the development of Scandinavian Blocking and Atlantic Ridge regimes, however the AWB-associated transient eddy fluxes actually work against it; other factors must be important

Swenson, E. T., and D. M. Straus, 2017: Rossby wave breaking and transient eddy forcing during Euro-Atlantic circulation regimes. ***J. Atmos. Sci., in press.***

GEORGE MASON UNIVERSITY

Thank you!

COLA